

Growth effect of Manchurian ash in mixed stands

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Abstract The growth of ash (*Fraxinus mandshurica*) in different mixed stands with larch (*Larix gmelini*), Korean pine (*Pinus koraiensis*) and spruce (*Picea koraiensis*) had been investigated. Meanwhile, the relationship between the growth gain of mixed stand and topographic factor, and the growth comparison of ash in pure and mixed stands with different age-stages were presented in this paper. The results show that the effect of ash and larch mixed stand is very significant. The growth gain of ash in mixed stand on east slope is better than that on west. The growth effect is the most significant on east upper slope and on west down slope. The growth of ash can be increased significantly during different age-stages, but of Larch only through its occupying dominant position in above-ground competition.

Key words: Mixed stand, Growth, Competition, Topographix factor

Introduction

The planting of *Fraxinus mandshurica* began at Shangzhi, Kedong, Yian and Fujin counties of Heilongjiang Province in 1960'. Ash (*Fraxinus mandshurica*) and larch (*Larix gmelini*), Ash and Korean pine (*Pinus koraiensis*) mixed stand were remained now, which were artificial, or formed by planting Ash after planting pure coniferous forest, or induced by establishing effect area in natural ash forest. There are many references on the growth of ash mixed stand in China. But in the past, the study of the relationship between the increasing growth of mixed stand with different age-stages and topographic factor is not sufficient, which is reported in this paper.

Outline of research location

The location is in Maorshan Forest Farm of Northeast Forestry University. This area is belong to the branch of Xiaoling, the west slope of Zhangguangcai Mountains, Changbai Mountain, and is typical lowly transition mountains from the eastern mountains of Northeast of China to Songnen Plain. The monsoon climate is obvious, and the annual average temperature, annual precipitation, evaporation, effective temperature is 2.8 °C, 723 mm, 1 093 mm, and 2 526 °C respectively in this area. The original forest was broad-leaved Korean pine mixed stand. The present forests are *Betula platyphylla*, *Populus davidiana*, *Quercus mongolica* and so on. The Qingnian Forest Farm of Qiqihar, Taidong Forest Farm of Fujin County, Dongxing Forest Farm of Kedong County of Heilong-

jiang Province were also investigated.

Investigating methods

In mixed young stand, one hundred trees in 1~3 lines were picked up in different slopes in different stands. The diameter, height and the recent 5 years' height increment of each tree were measured. The soil, plants and the ratio of mixed stand were reported.

In mixed mature stand, the fixed and temporary plots were set in 0.04 hm² of pure stand and 0.08 hm² of mixed stand. The diameter and height of each tree was measured. The stem analysis trees were cut, and each tree volume was obtained according to volume table.

Results and analysis

Effect of ash mixed with different trees

The increments of diameter, height and recent 5 years' height increased compared with the pure ash when mixed larch. But above factors increased in Ash-Korea pine and Ash-Spruce mixed stands. The growth index of different conifers in mixed stand increased except for that the growth of height of larch increased. Larch likes to grow in sunny climate, the ground diameter of which increased, Korean pine and spruce like to grow in gloomy environment. They were mixed with ash, which formed the dark environment, so the increment of Korean pine and spruce increased. It could draw a conclusion that the mixed stand of ash with larch, Korean pine and spruce were successful, and the effect of Ash-Larch mixed stand was the best (Table 1).

Table 1. The growth of mixed of young stands of ash with different trees

Stand	Location of slope	Species	Ground Diameter /cm	Tree height %	Recent 5 years' height increment /cm	%
Ash pure stand	East	Ash	3.744	100	269.8	100
Ash-larch mixed stand	East	Ash	4.158	111.0	307.4	113.1
		Larch	6.916	105.2	535.2	95.2
Larch pure stand	East	Larch	6.575	100	562.5	100
Ash-Korean mixed stand	East	Ash	3.151	79.3	247.2	89.0
		Korean pine	3.710	104.7	157.4	105.0
Korean pure stand	East	Korean pine	3.542	100	149.9	100
Ash-spruce mixed stand	East	Ash	2.762	69.5	205.6	74.1
		Spruce	3.443	105.6	150.7	101.9
Spruce pure stand	East	Spruce	3.261	100	147.9	100
					115.1	100

The Effect of different topographic factor on ash larch mixed stand

The ground diameter, height and recent 5 years' increment of ash increased by 11%, 13.1% and 19.6% respectively in the eastern slope of ash-larch mixed

stand compared with the west slope. But the ground diameter and height of larch increased by 3.4% and 3.1% respectively in the western slope compared with the eastern slope. The diameter of larch increased by 5.2% and increased by 4.8% in the eastern slope, both compared with pure stand. (Table 2).

Table 2. The comparison of the Ash-Larch young mixed stand at the different slope and the pure stand

Stand	Species	Location	Ground	Diameter	Tree	Height	The recent 5 years' height increment	
			/cm	%	/cm	%	/cm	%
Ash pure stand	Ash	East	Upper	3.25	100	301.6	100	243.9
			Middle	3.761	100	246.8	100	156.3
			Down	4.214	100	261.0	100	191.2
			Average	3.744	100	269.8	100	197.1
		West	Upper	4.745	100	360.7	100	277.6
			Middle	3.593	100	283.6	100	193.0
		East	Down	2.983	100	301.7	100	255.3
			Average	3.774	100	315.3	100	242.0
			Upper	7.119	100	657.1	100	-
Larch pure stand	Larch	West	Middle	6.610	100	519.5	100	-
			Down	5.995	100	511.0	100	-
			Average	6.575	100	562.5	100	-
			Upper	6.990	100	562.9	100	-
		East	Middle	6.246	100	500.0	100	-
			Down	6.391	100	486.4	100	-
		Ash	Average	6.542	100	516.4	100	-
			Upper	3.733	114.6	374.4	124.1	313.1
			Middle	4.063	107.3	247.7	100.4	156.8
Ash-larch mixed stand	Ash	West	Down	4.677	111.0	300.0	114.9	237.6
			Average	4.158	111.0	307.4	113.1	235.8
			Upper	5.586	78.6	502.0	76.4	-
		Larch	Middle	7.371	111.5	549.2	105.7	-
			Down	7.790	129.9	555.0	108.6	-
		Larch	Average	6.916	105.2	535.4	95.2	-
			Upper	5.260	110.9	369.5	102.4	299.5
			Middle	7.250	116.1	574.5	114.9	107.8
		West	Down	6.500	101.7	491.9	101.1	-
			Average	6.763	103.4	530.8	103.1	-

The ground diameter, height and recent 5 years' increment of Ash in mixed upper stand increased by 14.6%, 24.1% and 28.4% compared with pure stand. The growth effect of down slope was poor, and of the middle of the slope was the poorest. The growth increment of the western down slope was good, and of the middle was the poorest.

The growth effect of larch in mixed stand was different from that of Ash. The ground diameter and tree height increased by 29.9% and 8.6% respectively at the down slope, 11.5% and 5.7% at the middle slope respectively, and decreased at the upper slope. As for the western slope, the growth effect was the best in the middle slope, and not obvious at the down slope, and decreased at the upper slope.

Because of the biological and ecological characters of different trees, water and heat conditions of different slopes, the growth effect of above ash and larch mixed stand varied. There were lots of waters at the eastern slope. Light and heat were the main factors affected trees. In general, there was less heat at the eastern slope than at the western slope, but inversion in this area made the temperature of the eastern slope, especially the upper slope increased, adding to the ample water at the eastern slope. The growth

effect of ash at the eastern slope was better than that at the eastern slope, and especially was the best at the upper slope. Affected by water and nutrient, the growth effect of ash at the eastern down slope was only a little worse than that at the upper slope. The water and heat conditions at the middle slope were not satisfactory, so the growth effect was the worst there.

Water affected the western slope. The ample water at the western down slope promotes the growth of ash in the mixed stand, especially the growth of height. The water was less sufficient at the western upper slope than that of the down slope, but did not hinder trees to grow. At the same time, affected by inversion, the western upper slope had more waters, which promotes ash to grow.

The Growth Effect of Different Age stages

The diameter, tree height and single tree volume of Ash in different mixed stands increased by 17.6%~42.0%, 33.7%~47.1% and 92.1%~179.6% respectively. The above index of Larch increased 2.4%~9.0%, 2.8%~3.1% and 0.1%~20.4% respectively (Table 3).

Table 3. The comparison of the 15-year-old Ash-Larch mixed stand and pure stand

Stand	Species	D _{1.3}		H		V _{single}		M _{total}	
		/cm	%	/m	%	/m ³	%	/m ³ ·hm ⁻²	%
Pure stand	Larch	7.0	100	8.33	100	0.01484	100	69.748	100
Pure stand	Ash	3.6	100	4.73	100	0.0280	100	17.360	100
1L1A	Larch	7.7	109.0	8.59	103.1	0.01784	120.4	42.531	61.0
	Ash	4.7	132.7	6.14	142.3	0.00713	254.6	16.977	97.8
3L2A	Larch	7.1	100.4	8.32	100.0	0.01630	109.8	35.404	50.8
	Ash	5.1	142.0	6.96	147.1	0.00783	279.6	21.744	125.3
6L5A	Larch	6.9	97.6	8.07	97.2	0.01482	99.9	30.529	43.8
	Ash	4.2	117.6	6.33	133.7	0.00538	192.1	20.498	120.7

The 21 year-old and 26 year-old ash and larch grow more quickly in ash-larch mixed stand. The growth degree of larch was less than that of ash, because of the relationship of the above ground and underground species. Larch dominated above the ground and grew very quickly. Ash dominated under-

ground. Larch blocked ash, which promotes the photosynthesis of ash. The growth effect of ash was good, and of larch was bad at the western down slope, but the situation was contrary to that at the western middle slope (Table 4 and 5).

Table 4. The comparison of 21- year-old Ash-Larch mixed stand and pure stand

Stand	Species	D _{1.3}		H		V _{single}		M _{total}	
		(cm)	(%)	(m)	(%)	(m ³)	(%)	(m ³ /hm ²)	(%)
Pure stand	Larch	10.9	100	12.2	100	0.0530	100	79.5	100
	Ash	6.4	100	6.9	100	0.0191	100	44.312	100
Mixed stand	Larch	16.8	154	13.6	112	0.1458	275	72.90	91.7
	Ash	7.3	114	9.0	130	0.0259	136	30.821	69.5

SUMMARY

The mixed effect of Ash with different trees varied

obviously. The effect of ash and larch mixed stand was the best. The growth effect of Korean pine and spruce was good in Ash-Korean pine and Ash-Spruce

mixed stand in which the two tree species could be planted.

Table 5. The comparison of 26 year-old ash-larch mixed stand and pure stand

Stand	Species	D _{1.3}		H		V _{single}	
		/cm	%	/m	%	/m ³	%
Pure stand	Larch	11.0	100	10.6	100	0.0610	100
	Ash	4.7	100	6.1	100	0.0087	100
Mixed stand	Larch	12.7	110.4	11.0	113.8	0.0865	141.8
	Ash	6.1	129.8	8.3	136.1	0.0178	204.6

Affected by water, heat and inversion, the factors that affected trees changed at different slopes. In the ash young mixed stand, the growth effect was better at the eastern slope than at the western slope, and the best at the eastern upper slope. So the ash-larch mixed effect had a positive relationship with the qualities of location.

Ash-Larch mixed stand grew quickly at different age stages. Only dominating above the ground, did the growth of larch increase. The investigation in this area showed that the lowest height different that leaded to Larch to grow quickly should not be less than 3.0 m.

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